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(54) **COMPUTER VISION SYSTEM FOR TRACKING BALL MOVEMENT AND ANALYZING USER SKILL**

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G06T 7/00 (2006.01)
G06T 7/20 (2006.01)
G06T 11/60 (2006.01)

(52) **U.S. Cl.**

CPC ***G06T 7/20*** (2013.01); ***G06T 7/0042*** (2013.01); ***G06T 11/60*** (2013.01); *G06T 2207/30224* (2013.01)

(58) **Field of Classification Search**

CPC G06T 7/0042; G06T 7/20; G06T 11/60; G06T 2207/30224

See application file for complete search history.

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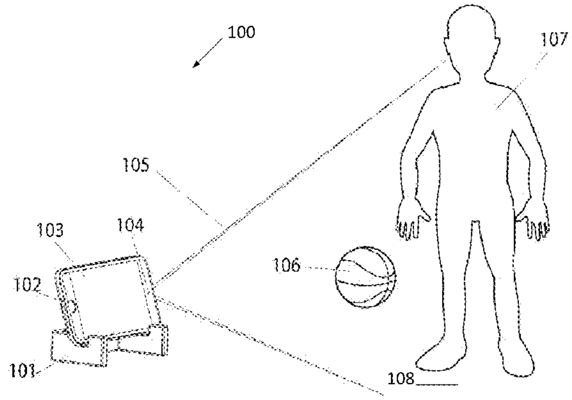
(57) **ABSTRACT**

A computer processor of the mobile device may overlay a shape graphic on a fixed area of a screen of the mobile device. A camera of the mobile device may search the fixed area for a ball with a marking. The computer processor may recognize the marking on the ball. The computer processor may calibrate the movement of the ball in the overlayed shape graphic in view of the recognized marking of the ball. The camera may track and may record data pertaining to the movement of the ball. The computer processor may calculate one or more metrics relating to ball controlling abilities from the data. The computer processor may display the one or more metrics on the screen.

27 Claims, 8 Drawing Sheets



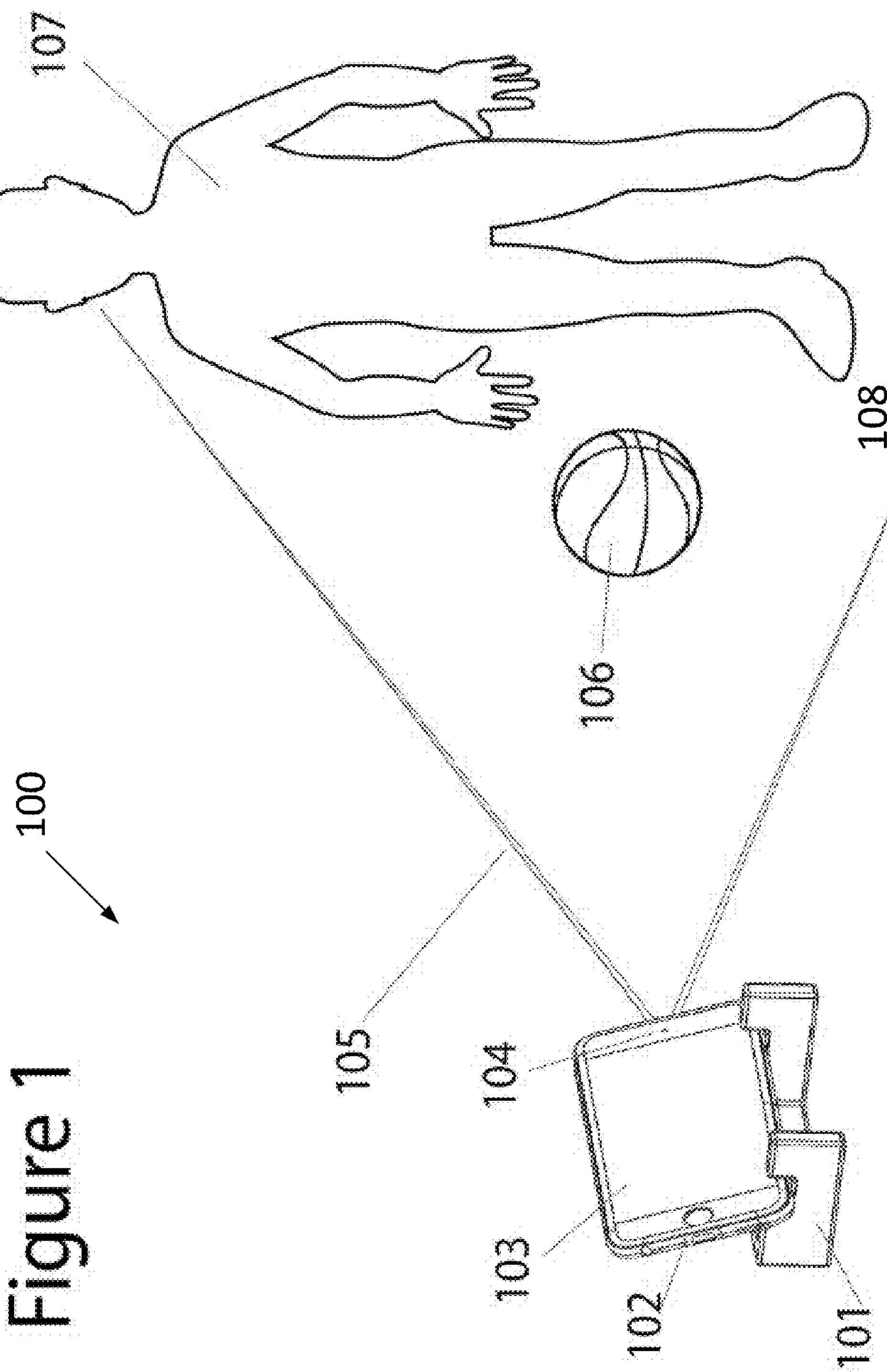


Figure 1

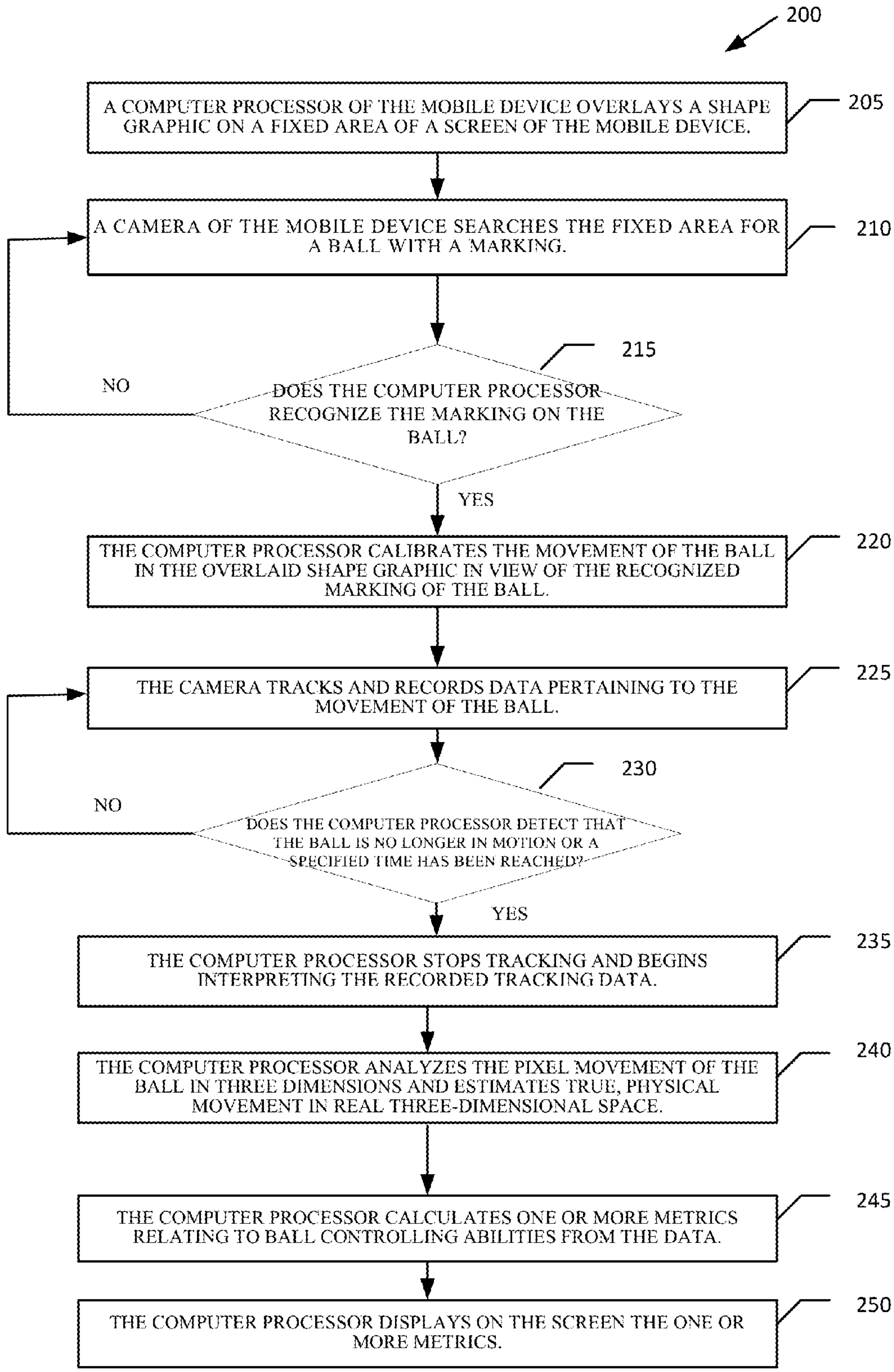

200
A COMPUTER PROCESSOR OF THE MOBILE DEVICE OVERLAYS A SHAPE GRAPHIC ON A FIXED AREA OF A SCREEN OF THE MOBILE DEVICE.
205
A CAMERA OF THE MOBILE DEVICE SEARCHES THE FIXED AREA FOR A BALL WITH A MARKING.
210
DOES THE COMPUTER PROCESSOR RECOGNIZE THE MARKING ON THE BALL?
215
NO
YES
THE COMPUTER PROCESSOR CALIBRATES THE MOVEMENT OF THE BALL IN THE OVERLAID SHAPE GRAPHIC IN VIEW OF THE RECOGNIZED MARKING OF THE BALL.
220
THE CAMERA TRACKS AND RECORDS DATA PERTAINING TO THE MOVEMENT OF THE BALL.
225
DOES THE COMPUTER PROCESSOR DETECT THAT THE BALL IS NO LONGER IN MOTION OR A SPECIFIED TIME HAS BEEN REACHED?
230
NO
YES
THE COMPUTER PROCESSOR STOPS TRACKING AND BEGINS INTERPRETING THE RECORDED TRACKING DATA.
235
THE COMPUTER PROCESSOR ANALYZES THE PIXEL MOVEMENT OF THE BALL IN THREE DIMENSIONS AND ESTIMATES TRUE, PHYSICAL MOVEMENT IN REAL THREE-DIMENSIONAL SPACE.
240
THE COMPUTER PROCESSOR CALCULATES ONE OR MORE METRICS RELATING TO BALL CONTROLLING ABILITIES FROM THE DATA.
245
THE COMPUTER PROCESSOR DISPLAYS ON THE SCREEN THE ONE OR MORE METRICS.
250

FIGURE 2

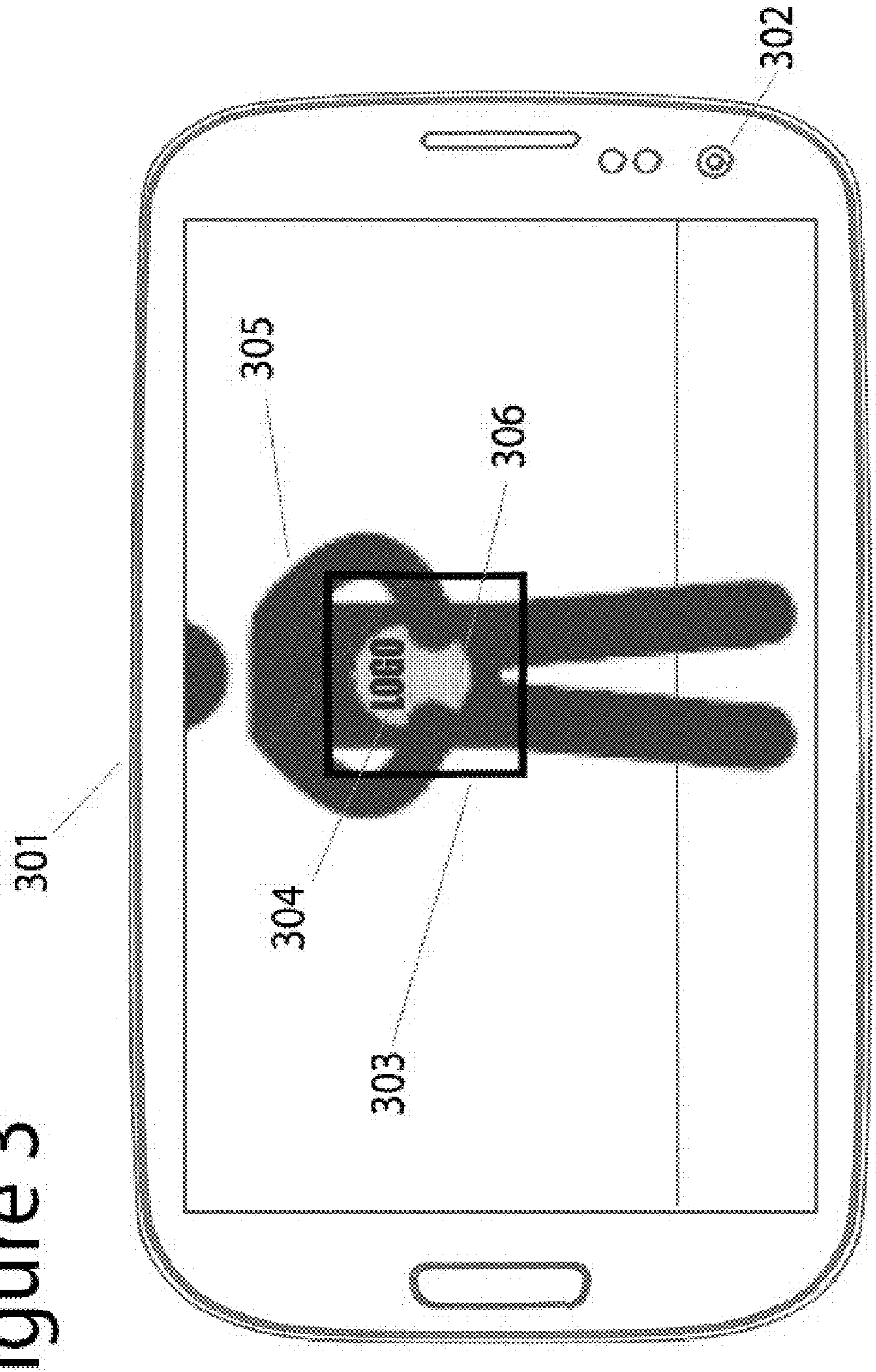


Figure 3

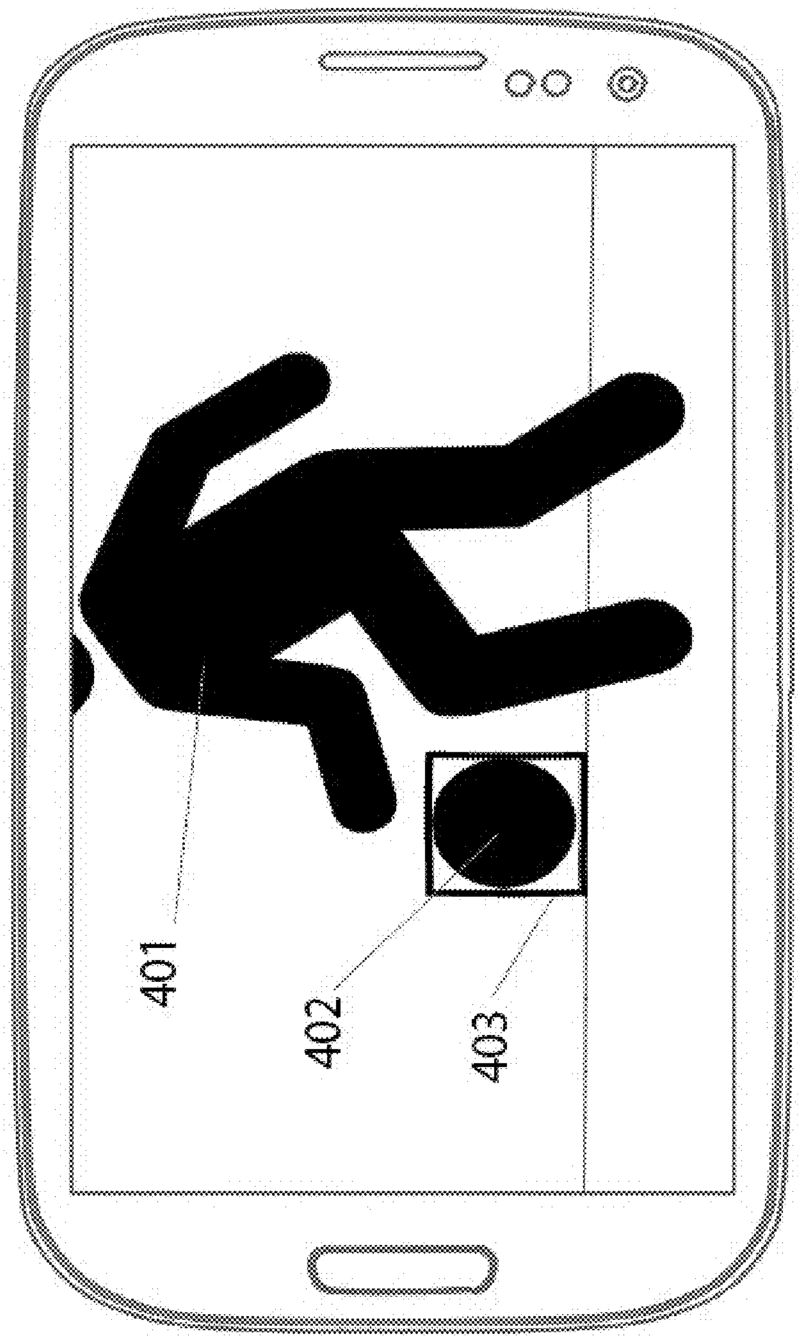


Figure 4

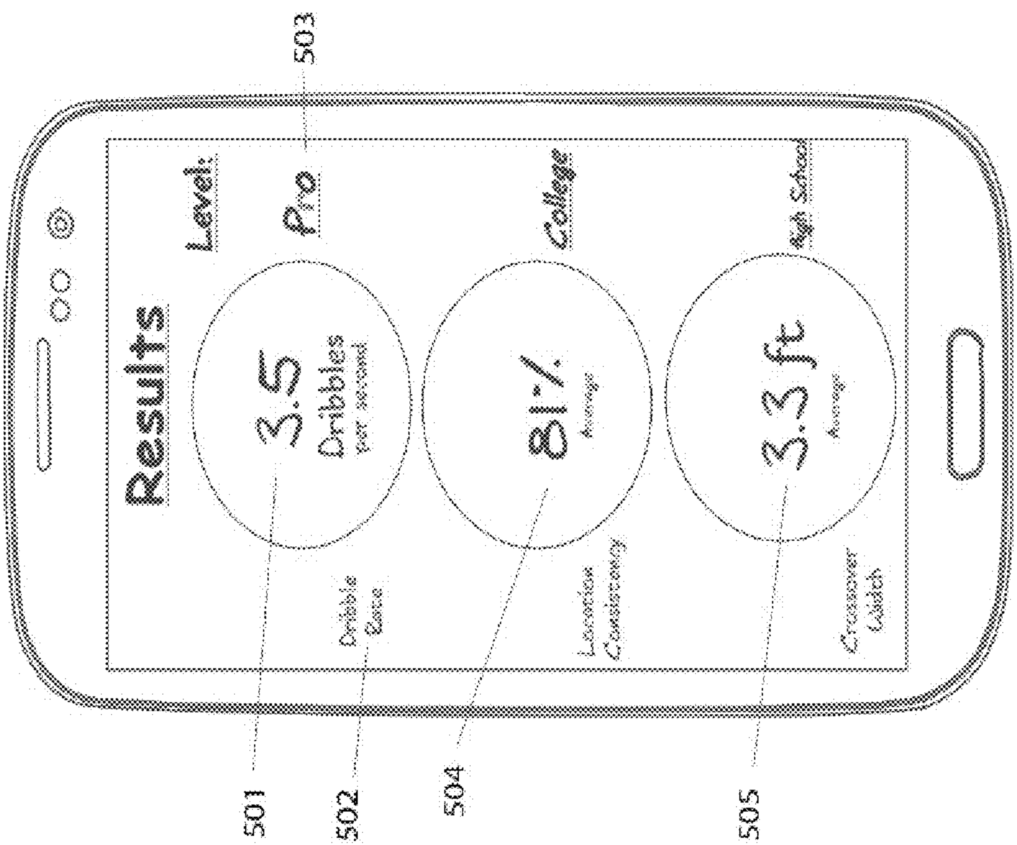

Results
Level:
Pro
College
High School
3.5
Dribbles
per second
81%
Average
3.3 ft
Average
Dribble Rate
Location Consistency
Crossover Width
501
502
503
504
505

Figure 5

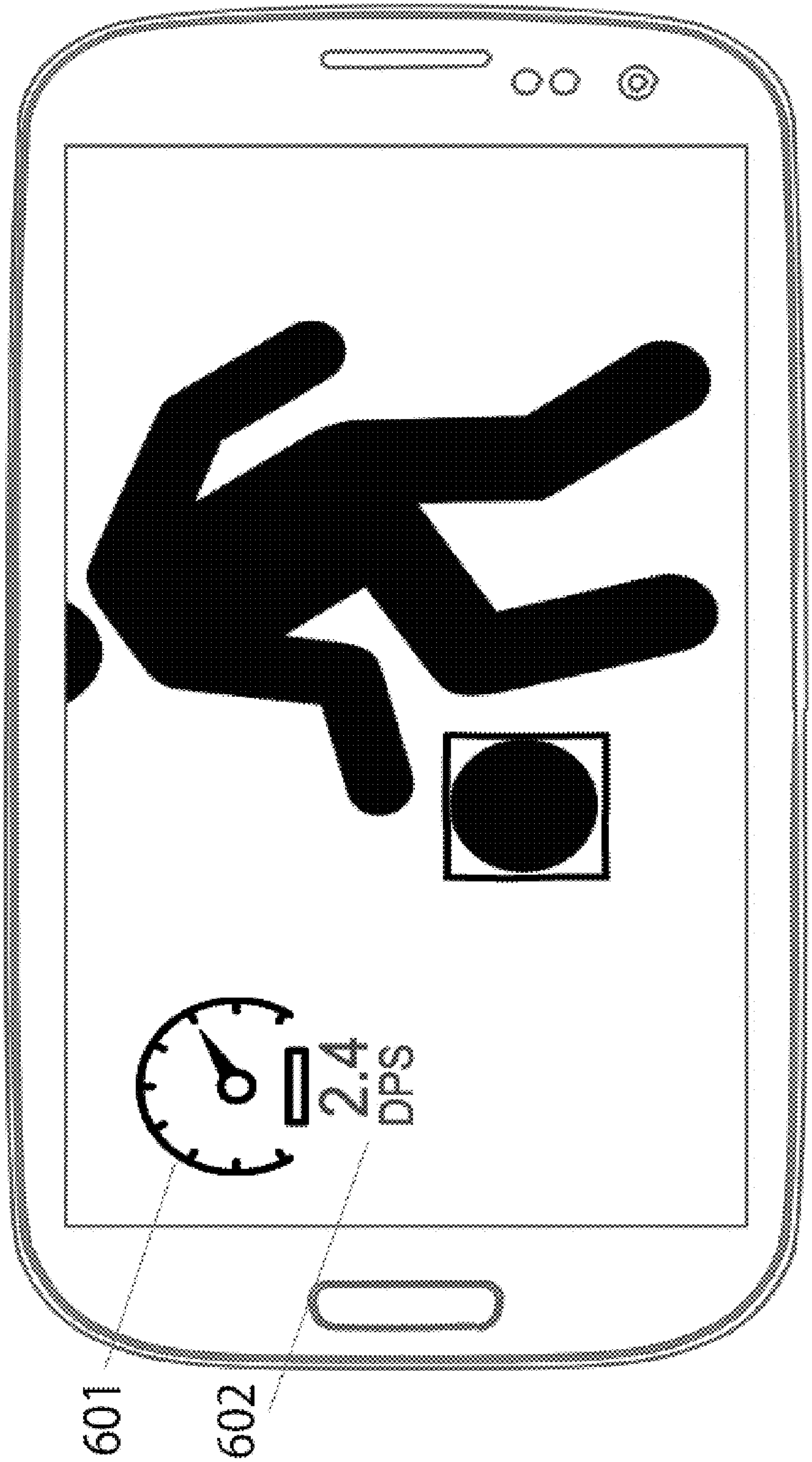


Figure 6

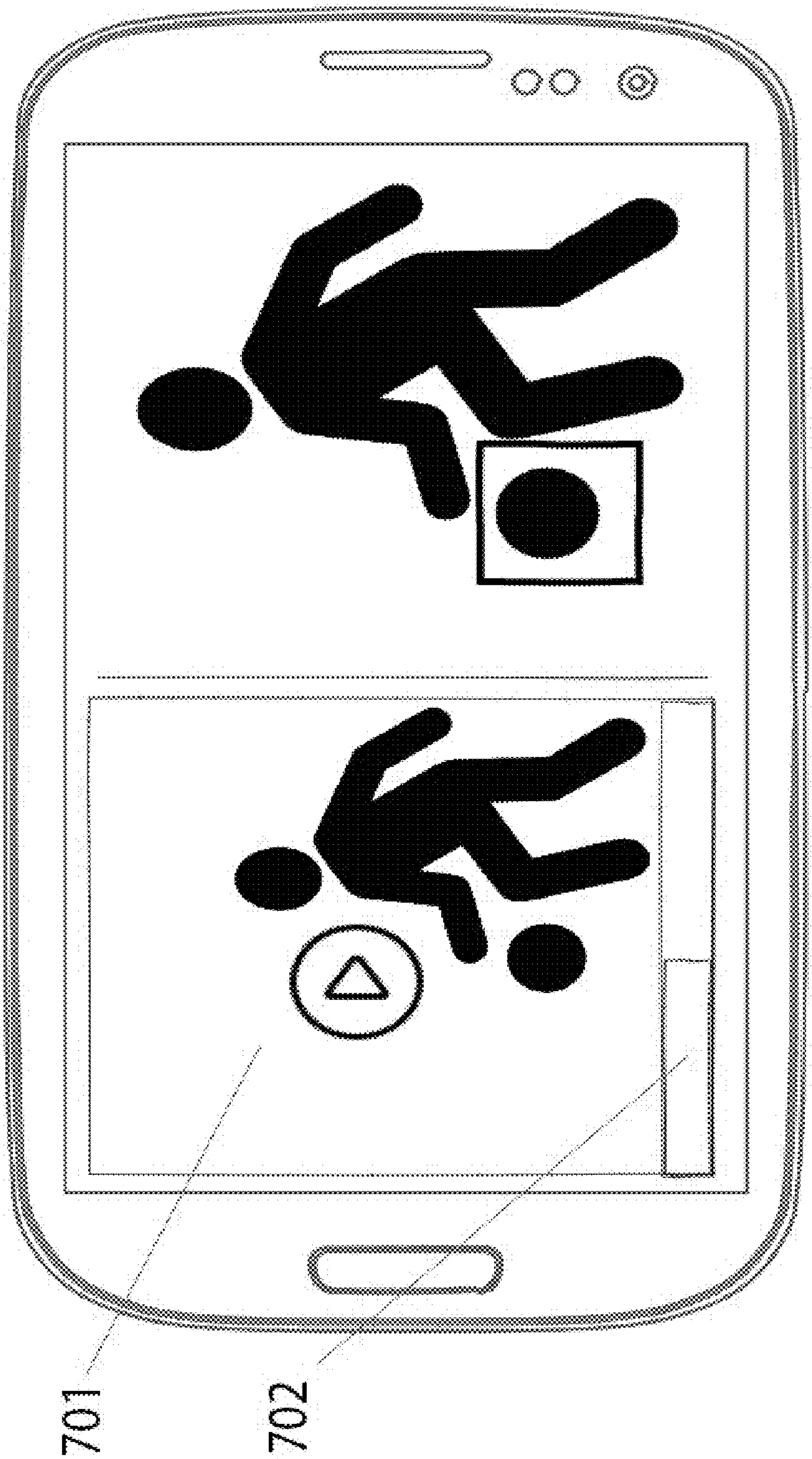


Figure 7

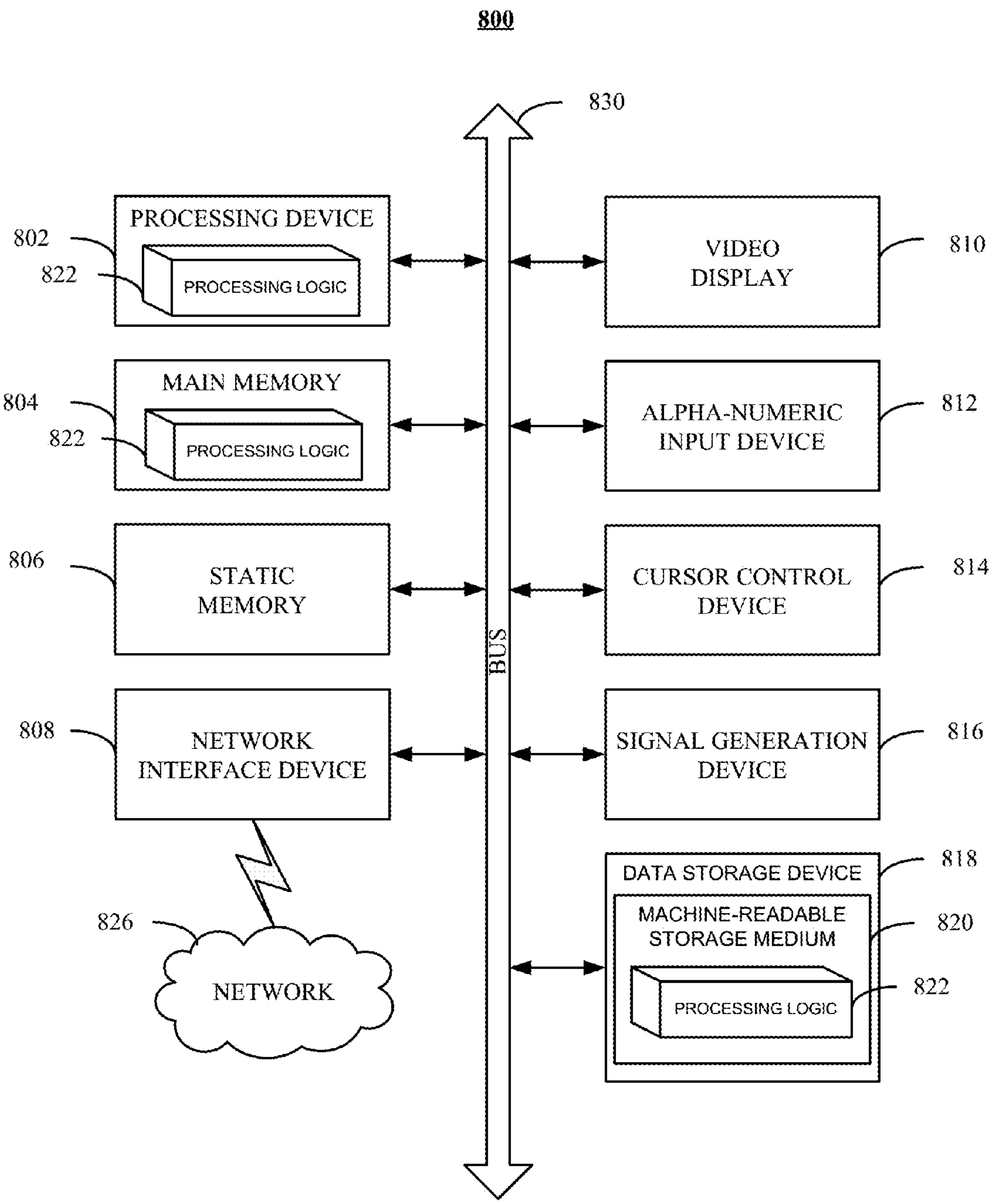

800
830
PROCESSING DEVICE
802
822
PROCESSING LOGIC
MAIN MEMORY
804
822
PROCESSING LOGIC
806
STATIC MEMORY
808
NETWORK INTERFACE DEVICE
826
NETWORK
BUS
VIDEO DISPLAY
810
ALPHA-NUMERIC INPUT DEVICE
812
CURSOR CONTROL DEVICE
814
SIGNAL GENERATION DEVICE
816
DATA STORAGE DEVICE
818
MACHINE-READABLE STORAGE MEDIUM
820
PROCESSING LOGIC
822

FIGURE 8

COMPUTER VISION SYSTEM FOR TRACKING BALL MOVEMENT AND ANALYZING USER SKILL

TECHNICAL FIELD

The present invention relates generally to a system and method for tracking and analyzing a user's interaction with a ball, such as a basketball, soccer ball, etc. More specifically, the invention relates to a mobile device positioning apparatus and a computer vision method. The computer vision method is embodied in software that runs on a mobile device that tracks the movement of a ball over a period of time. This method enables the production of metrics relating to ball control, such as dribble rate, when used with a basketball.

BACKGROUND

In the field of athletics, especially in soccer and basketball, a player's control of the ball is essential to the player becoming a proficient athlete. In basketball, one main aspect of ball control is the player's ability to dribble the ball with maximum control and speed. In soccer, there are a variety of drills to increase ball control, such as ball juggling, which involves keeping the ball in the air by repeatedly kicking it up.

As both soccer and basketball have evolved with new technological advances, there has been an increasing demand for the quantification of a player's skills with respect to handling of the ball. However, the existing means for the average person to measure this skill is very limited, as well as costly.

The related art that provides quantified feedback to basketball users is limited to basketballs containing motion sensors, which measure the player's ball control abilities. These basketballs send users their data via Bluetooth to a mobile smart phone, which displays feedback such as the player's average number of dribbles per second. However, these sensor-enabled basketballs are required to be periodically charged, thereby limiting the portability of the product. Moreover, these expensive sensor embodied basketballs are limited only to data which can be derived from the sensors inside the ball. For example, average dribble height, relative location of the ball, crossover width and other analytical measurements cannot be determined by these basketballs, thus providing the user with very limited feedback regarding his or her dribbling abilities. Other than these expensive sensor-embodied basketballs, there is no other system for the average person to evaluate his ball control abilities.

The related art pertaining to soccer is similar, which is limited to sensor-embodied balls that provide feedback. However, these sensor-embodied balls are overly expensive and inconvenient because they must be periodically charged. Moreover, just as in the case of sensor basketballs, the analytic feedback provided to a user is limited only to the information that the inner sensors can provide.

SUMMARY

The above-described problems are addressed and a technical solution is achieved in the art by providing an apparatus and a method for tracking and analyzing a user's interaction with a ball, such as a basketball, soccer ball, etc., to provide the user with an evaluation of his ball control skills. In the case of basketball, these ball controls abilities include, but are not limited to, dribble rate, crossover-width, location consistency, maximum dribble height, dribble rate variance, dribble speed, and dribble fatigue. In the case of soccer, these ball controls abilities include juggle location consistency, maximum height, and number of juggles. The aforementioned apparatus is a mechanical holder for a mobile device, such as a tablet or smartphone, that positions the device camera at a high enough angle, typically between sixty and ninety degrees, to video capture the user, the ball, and the floor. The method embodied as software utilizes computer vision technology running on a mobile device with a front facing camera. The software identifies a ball and tracks the movement of the ball, as it is being manipulated by the user. As the system is tracking the movement of the ball using the camera, a live video feed is displayed on the mobile device screen, facing the user, with a shape overlayed on the ball's position. The system then analyzes and interprets the movement of the ball to determine specific metrics that relate to the user's ball control abilities.

The above-described problems are addressed and a technical solution is achieved in the art by providing a method for tracking and analyzing a user's interaction with a ball. A computer processor of the mobile device may overlay a shape graphic on a fixed area of a screen of the mobile device. A camera of the mobile device may search the fixed area for a ball with a marking. In one example, the camera may be a front-facing camera of the mobile device. In one example, the marking may be a logo.

The computer processor may recognize the marking on the ball. The computer processor may calibrate the movement of the ball in the overlayed shape graphic in view of the recognized marking of the ball. The camera may track and record data pertaining to the movement of the ball. The computer processor may calculate one or more metrics relating to ball controlling abilities from the data. The computer processor may display on the screen the one or more metrics. In one example, the computer processor may calculate the one or more metrics and may display the one or more metrics responsive to the computer processor detecting that the ball is no longer in motion or a specified time has been reached. In an example, the one or more metrics, e.g., dribble rate, may be calculated and displayed to the user in real-time. In one example, the one or more metrics may be calculated and displayed while ball tracking pertaining to the movement of the ball is taking place.

In an example, the computer processor recognizing the marking on the ball may apply to balls with specific brands or markings. Recognizing the markings on the ball may further comprise applying feature recognition computer vision algorithms to data captured by the computer processor pertaining to the marking. The feature recognition computer vision algorithms may comprise at least one of cross-correlation feature recognition or image matching. The marking may be recognized based on at least one of image, text, or shape.

In an example, calibrating may further comprise the computer processor recognizing one or more colors of the marking and the ball, lighting conditions, or ball pixel diameter. The computer processor may determine ball color spectrum for color blob detection while tracking the movement of the calibrated ball.

In an example, the computer processor tracking the movement of the calibrated ball may comprise the computer processor employing color blob detection, shape recognition, or movement filtering.

In an example, the computer processor may display on the screen a live video feed while the computer processor is tracking the ball.

In an example, responsive to the camera tracking position of the ball on the screen, the computer processor may calculate and store the centroid of the ball, a frame timestamp, and a ball pixel diameter in a memory. The computer processor may estimate depth movement of the ball by examining ball pixel area in the recorded tracking data. The computer processor estimating depth movement of the ball may comprise the computer processor comparing the pixel diameter of the ball to the original pixel diameter acquired during calibration. The computer processor may look up, in a memory of the mobile device, preloaded diameter of the ball corresponding to the marking detected and dynamically determine physical scale for different balls with different markings. The computer processor may convert pixel tracking to physical tracking of the ball in a three-dimensional space in view of determining physical scale. The computer processor may analyze pixel movement of the ball in three dimensions and estimate true physical movement in real three-dimensional space.

In one example, the ball may be a basketball and the one or more metrics may comprise at least one of dribble rate, cross-over-width, location consistency, maximum dribble height, dribble rate variance, dribble speed, or dribble fatigue. In one example, the ball may be a soccer ball and the one or more metrics may comprise at least one of juggle location consistency, maximum height, or number of juggles.

In an example, the mobile device may provide a training program that employs the data.

The above-described problems are addressed and a technical solution is achieved in the art by providing a mobile device for tracking and analyzing a user's interaction with a ball.

The mobile device may comprise a memory, a computer processor, operatively coupled to the memory, a screen, coupled to the computer processor; and a camera, coupled to the computer processor. The camera may be configured to search a fixed area of the screen for a ball with a marking and track and record data pertaining to the movement of the ball. The computer processor may be configured to overlay a shape graphic on the fixed area of the screen, recognize the marking on the ball, and may calibrate tracking of the ball in the overlayed shape graphic in view of the recognized marking of the ball. The computer processor may calculate one or more metrics relating to ball controlling abilities from the data and may display on the screen the one or more metrics. In an example, the one or more metrics, e.g., dribble rate, may be calculated and may be displayed to the user in real-time. In one example, the one or more metrics may be calculated and may be displayed while ball tracking pertaining to the movement of the ball is taking place.

In an example, the mobile device may be provided with comprising a positioning apparatus. The mobile device may be configured to be placed in the positioning apparatus. The mobile device may be configured to be placed in the positioning apparatus at a high enough angle to permit video capture of the ball, the user, and a floor on which the user stands. The angle may be between sixty and ninety degrees.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be more readily understood from the detailed description of exemplary embodiments considered in conjunction with the following drawings, of which:

FIG. **1** illustrates a perspective view of a system for tracking and analyzing ball movement.

FIG. **2** is a process flow diagram illustrating mobile device interacting with the user, tracking the ball, and determining metrics.

FIG. **3** illustrates a mobile device screenshot before and during calibration.

FIG. **4** illustrates the mobile device screen tracking the position of the ball as it moves in the field of view of the mobile device's camera.

FIG. **5** illustrates metrics that may be displayed to the user on the mobile device screen.

FIG. **6** illustrate a mobile device screenshot with live metric overlayed during tracking.

FIG. **7** illustrates the tracking system utilized with a training program.

FIG. **8** illustrates a diagrammatic representation of a machine in the example form of a computer system within which a set of instructions, for causing the machine to perform any one or more of the methodologies discussed herein, may be executed.

DETAILED DESCRIPTION

FIG. **1** illustrates a perspective view of a system **100** for tracking and analyzing ball movement. In one example, a mobile device **102** may be held in the positioning apparatus **101** with the built-in camera **104** capturing video. In one example, the built-in camera **104** may be a front-facing camera **104** of the mobile device **102**. In another example, the mobile device **102** may be propped up against an object at an appropriately high angle. The mobile device **102** may run ball tracking and analyzing software, and may display a live video feed on the device screen **103** while ball tracking. The front-facing camera **104**, coupled to the front-facing device screen **103**, permits the mobile device **102** to be used as a personal ball tracking and skill evaluation system. As is shown in FIG. **1**, the positioning apparatus **101** may be angled at a high enough angle to allow video capture of the ball **106**, the user **107**, and the floor **108**. Most mobile device positioning stands available commercially position the mobile device screen at a relatively low angle, such as 45 degrees, to allow easy viewing from a desktop. This low angle, however, does not give permit users **107** to view their movements on the front-facing camera **104** when the device **102** and the stand **101** are on the floor **108** and the user **107** is standing some distance away. On the contrary, the high angle of the mobile device positioning apparatus **101** permits easy viewing from a distance, such as for a user dribbling a basketball several feet away from the mobile device **102**. Furthermore, the high angle of the positioning apparatus **101** permits camera capture of the complete view **105** of the environment, including the floor **108**.

FIG. **2** is a process flow diagram illustrating an example of a method **200** for the mobile device **102** interacting with the user **107**, tracking the ball **106**, and determining metrics. The method **200** may be performed by a computer system **800** of FIG. **8** which encompasses the computer processor (not shown) of the mobile device **102** of FIG. **1** and may comprise hardware (e.g., circuitry, dedicated logic, programmable logic, microcode, etc.), software (e.g., instructions run on a processing device), or a combination thereof. In one example, the method **200** may be performed by a computer processor (not shown) of the mobile device **102** of FIG. **1**.

A computer processor (not shown) of the mobile device **102** may provide a calibration screen **201**, as depicted in FIG. **3**.

As illustrate in FIG. **2**, at block **205**, the computer processor of the mobile device **102** may overlay a shape graphic **303** on a fixed area of a screen **103** of the mobile device. The shape **303** may cover a fixed, small area of the screen. At block **210**, the camera **104** the mobile device **102** may continuously search **202** the small area covered by the shape graphic **303** for a ball **306** with a specific marking **304**. In an example, the marking **304** may be a logo. From a processing perspective, only the fixed area **303** is scanned for the marking **304**, as opposed to scanning the entire video frame, permitting faster and/or more accurate processing and marking recognition. In an example, specific marking templates may be preloaded into the software, so that the mobile device **102** recognizes specific markings **304** and intentionally ignores balls **306** with other markings.

Marking recognition provides a form of access control, whereby the mobile device **102** may run only for balls with specific brands or markings. This is advantageous for restricting use of the software of the mobile device **102** for users of only specific brands of balls **306**. Marking or brand recognition is accomplished via common feature recognition computer vision algorithms, such as cross correlation feature recognition and/or image matching. The markings that the mobile device **102** recognizes and grants access to may be preloaded in the software before software execution. Markings may be any image, text, or shape. Additionally, marking recognition may permit the user **107** to start the calibration/tracking deliberately and with intention. The user **107**, **305** may move the ball **106**, **306** around and get comfortable, but the mobile device **102** may only calibrate and start tracking when the user **305** shows the marking **304** in the overlayed shape **303** in the calibration screen of FIG. **3**.

If, at block **215**, the computer processor of the mobile device **102** recognizes an authorized marking **304** on a ball **306**, then at block **220**, the computer processor of the mobile device **102** may calibrate the movement of the ball **306** detected in the overlayed shape **303** in view of the recognized marking **304** of the ball **306**. If, at block **215**, the computer processor of the mobile device **102** does not recognize an authorized marking **304** on a ball **306**, then processing returns to block **210** (searching the fixed area for a ball with a logo).

Calibration in this case may refer to sensing the marking-authenticated ball's **306** colors, lighting conditions, and/or ball pixel diameter. The mobile device **102** may then store this ball's **306** characteristic data into a memory (not shown) for more accurate tracking, such as determining ball color spectrum for color blob detection while ball tracking. Calibration is necessary because balls for the same sport are produced in non-identical colors, e.g., basketballs may be orange or brown, and environmental lighting is never the same, e.g., fluorescent indoor lighting and outdoor sunlight. This specific manner of calibration is advantageous because the mobile device **102** may only need to analyze a small area **303** of the video frame where it is known that there is a basketball, as opposed to scanning the entire video frame searching for an object with similar features to a ball profile preloaded in the memory. Focusing on only a specific, small area **303** of the video frame permits the mobile device **102** to use higher resolution and/or faster processing—so the mobile device **102** can more accurately sample the ball's **306** colors, shape, and/or shading.

After the automatic calibration is complete, at block **225**, the camera **104** may track and may record data pertaining to the movement of the ball **306** that was sensed. The mobile device **102** may utilize well-established computer vision algorithms with custom parameters determined during calibration. The tracking algorithm may employ a technique such as color blob detection, shape recognition, and movement filtering. FIG. **4** illustrates the mobile device screen **301** tracking the position of the ball **402** as it moves in the field of view of the mobile device's camera **104**, **302**. As the mobile device **102** tracks the position of the ball **402** on screen, at block **206**, the mobile device **102** may store the centroid position (in X and Y pixel coordinates) of the ball **106**, a frame timestamp, and a ball pixel diameter **206** in the memory. In an example, the one or more metrics, e.g., dribble rate, may be calculated and displayed to the user in real-time. In one example, the one or more metrics may be calculated and displayed while ball tracking pertaining to the movement of the ball is taking place.

In an example, if, at block **230**, the computer processor of the mobile device **102** detects that the ball **402** is no longer being manipulated by the user **205**, e.g., the position of the ball remains relatively motionless for greater than a predetermined amount of time, e.g., five seconds or more, then at block **235**, the mobile device **102** may stop tracking and may begin interpreting the recorded tracking data **206**. In another example, the mobile device **102** may be configured to automatically stop tracking after a set amount of time, e.g., after 30 seconds. If, at block **230**, the computer processor of the mobile device **102** detects that the ball **402** is still being manipulated by the user **205**, then processing returns to block **225** (tracking and recording data pertaining to the movement of the ball).

In addition to analyzing horizontal and vertical movement, the mobile device **102** may estimate depth movement (in the Z-axis) of the ball **402**, by examining ball pixel area in the recorded tracking data. By comparing the pixel diameter of the ball **402** to the original pixel diameter acquired during calibration, the mobile device **102** can estimate relative movement in the depth axis.

The mobile device **102** may analyze the pixel diameter of the tracked ball **402** and use that as a scale for physical measurements. Many balls for specific sports have regulated diameters, so the scale is preloaded and well known. The mobile device **102** may look up the preloaded diameter of the basketball corresponding to the logo detected, allowing the mobile device **102** may to dynamically determine physical scale for different balls with different logos. The mobile device **102** may employ a linear mathematical equation then relates pixels to physical dimensions, such as inches or centimeters. By the mobile device **102** estimating physical scale, via analyzing ball pixel diameter, of every video frame or just of the first calibration frame, the mobile device **102** may convert pixel tracking to physical tracking in a three-dimensional space. In a theoretical example, if the ball **402** has a diameter of one hundred pixels and corresponds to a true diameter of ten inches, a horizontal movement of five hundred pixels for the ball may correspond with fifty inches horizontal displacement.

At block **240**, the computer processor of mobile device **102** may analyze the pixel movement of the ball in three dimensions and estimates true, physical movement in real three-dimensional space. At block **245**, the mobile device **102** may then proceed to calculate one or more metrics that relate to an individual's ball controlling abilities from the data. At block **250**, the mobile device may display the one or more metrics and interpretations on the screen **104** to the user **205**.

In one example, the ball tracked may be a basketball. The metrics determined relate to dribbling, an important skill for basketball players. Dribbles may be determined by analyzing the movement of the ball **106**, **402** in the Y-axis (vertical direction) and calculating relative maxima. One dribble is considered one bounce of the ball **106**, **402** on the floor **108**, expressed in camera movement as a downward motion followed by an upward motion. The mobile device **102** may identify with which hand the ball is being dribbled, and may indicate this characteristic in the tracking data. The mobile device **102** may differentiate with which hand the ball is being dribbled by examining relative horizontal locations of dribbles. If a dribble occurs on the left side of the screen and another dribble occurs on the right side of the screen, the mobile device **102** may differentiate the two and establishes a horizontal position threshold for differentiating left and right dribbles.

A crossover is a more advanced dribble used by basketball players. It is a dribble on an angle that crosses from the left to the right arms, and vice versa, literally crossing over from one side to the other. A crossover is detected by searching for dribbles that have an absolute change in position on the X-axis (horizontal direction) higher than a specific threshold. Direction of the crossover, whether left or right, is determined by examining the direction of the ball's movement.

For the basketball application of this invention, the metrics calculated may relate to dribble rate, crossover-width, location consistency, maximum dribble height, dribble rate variance, dribble speed, or dribble fatigue. Dribble rate may be determined by calculating the total number of dribbles per second. Dribble rate variation may be calculated by examining change in dribble rates over the period of time that the ball was tracked. Maximum dribble height may be determined by seeking the highest vertical position of the ball. Dribble consistency may be determined in three dimensions by calculating the relative standard deviation of dribbles in space. If crossover dribbles were detected, the mobile device **102** may calculate crossover consistency in a similar fashion. Crossover width may be calculated by examining the horizontal displacement of the ball **106**, **402** during a crossover dribble event. The mobile device **102** may separately calculate left crossover dribble rate and right crossover dribble rate. The mobile device **102** may also separately calculate metrics separately for left and right non-crossover dribbles.

The metrics may be displayed to the user **107** on the mobile device screen **103**, **301**, as shown in FIG. **5**. Metrics may be displayed in physical units **501**, **505**, or as a percentage **504**. The mobile device **102** may compare the metrics calculated with preloaded ranges corresponding to skill level **503**. For example, skill level may be pro, college, or amateur. The mobile device **102** may also generate training suggestions based on the calculated metrics, such as comparing left and right hand dribble metrics. For example, if the dribble consistency of the left side is more accurate than the dribble consistency of the right hand, the mobile device **102** may suggest to the user **107** to practice dribbling with the right hand. Calculated metrics may be transmitted from the mobile device **102** to a web server or social media site, or sent via message or data transfer to another recipient. Users **107** may compete with each other by comparing calculated metrics with other users **107**.

In one example, the mobile device **102** may display metrics on screen while tracking the ball, as shown in FIG. **6**. Metrics may be calculated live (e.g., in real time); average metrics may be running averages that update. For example, a dribble counter would increment live with every dribble that the mobile device **102** detects. Dribble rate and dribble speed may be calculated simultaneously as tracking progresses, and then overlaid **602** on the tracking screen. An icon **601**, such as a speedometer, may be displayed next to the metric being calculated live to provide a visual indication and descriptor.

In one example, the tracking system may be provided with a training program, as shown in FIG. **7**. A training video **701** of a character or person executing dribbling actions plays side by side with the ball tracking screen. After the training video finishes, the tracking stops and the mobile device **102** may compare the optimal ball movements—the movements that are displayed in the training video **701**, with the movements that the user **107** completed in reality. The mobile device **102** may compare reaction rate, e.g., the time difference between what is displayed on the instructional video and when the user **107** completes that movement. The mobile device **102** may interpret overall success rate of the user **107** by comparing how well the ball movements of the user **107** match the instructional video character's ball movements.

In another example, the sport involved is soccer. With soccer, the computer vision system within the mobile device **102** may focus on juggling, as opposed to dribbling. The one or more metrics may related to juggle location consistency, maximum height, or number of juggles. A juggle is detected similarly to a dribble, by analyzing the Y-axis movement of the ball **106** and calculating local maxima. One juggle is the upward Y-axis movement followed by a downward Y-axis movement. Metrics may be calculated live (e.g., in real time), for example, a juggle counter would increment live with every juggle that the mobile device **102** detects. The juggle counter would reset upon detection of a juggle interruption, such as, but not limited to, the soccer ball hitting the floor (determined by the Y axis movement of the ball). The mobile device **102** may calculate metrics similar to basketball metrics, including but not limited to, juggle location consistency, maximum height, and number of juggles.

FIG. **8** illustrates a diagrammatic representation of a machine in the exemplary form of a computer system **800** within which a set of instructions, for causing the machine to perform any one or more of the methodologies discussed herein, may be executed. In alternative embodiments, the machine may be connected (e.g., networked) to other machines in a local area network (LAN), an intranet, an extranet, or the Internet. The machine may operate in the capacity of a server or a client machine in a client-server network environment, or as a peer machine in a peer-to-peer (or distributed) network environment. The machine may be a personal computer (PC), a tablet PC, a set-top box (STB), a personal digital assistant (PDA), a cellular telephone, a web appliance, a server, a network router, switch or bridge, or any machine capable of executing a set of instructions (sequential or otherwise) that specify actions to be taken by that machine. Further, while only a single machine is illustrated, the term "machine" shall also be taken to include any collection of machines that individually or jointly execute a set (or multiple sets) of instructions to perform any one or more of the methodologies discussed herein.

The exemplary computer system **800** includes a processing device **802**, a main memory **804** (e.g., read-only memory (ROM), flash memory, dynamic random access memory (DRAM) (such as synchronous DRAM (SDRAM) or Rambus DRAM (RDRAM), etc.), a static memory **806** (e.g., flash memory, static random access memory (SRAM), etc.), and a data storage device **818**, which communicate with each other via a bus **830**.

Processing device **802** represents one or more general-purpose processing devices such as a microprocessor, central processing unit, or the like. More particularly, the processing device may be complex instruction set computing (CISC) microprocessor, reduced instruction set computer (RISC) microprocessor, very long instruction word (VLIW) microprocessor, or processor implementing other instruction sets, or processors implementing a combination of instruction sets. Processing device **802** may also be one or more special-purpose processing devices such as an application specific integrated circuit (ASIC), a field programmable gate array (FPGA), a digital signal processor (DSP), network processor, or the like. Processing device **802** is configured to execute processing logic **822** for performing the operations and steps discussed herein.

Computer system **800** may further include a network interface device **808**. Computer system **800** also may include a video display unit **810** (e.g., a liquid crystal display (LCD) or a cathode ray tube (CRT)), an alphanumeric input device **812** (e.g., a keyboard), a cursor control device **814** (e.g., a mouse), and a signal generation device **816** (e.g., a speaker).

Data storage device **818** may include a machine-readable storage medium (or more specifically a computer-readable storage medium) **820** having one or more sets of instructions embodying any one or more of the methodologies of functions described herein. Processing logic **822** may also reside, completely or at least partially, within main memory **804** and/or within processing device **802** during execution thereof by computer system **800**; main memory **804** and processing device **802** also constituting machine-readable storage media. Processing logic **822** may further be transmitted or received over a network **826** via network interface device **808**.

Machine-readable storage medium **820** may also be used to store the processing logic **822** persistently. While machine-readable storage medium **820** is shown in an exemplary embodiment to be a single medium, the term "machine-readable storage medium" should be taken to include a single medium or multiple media (e.g., a centralized or distributed database, and/or associated caches and servers) that store the one or more sets of instructions. The term "machine-readable storage medium" shall also be taken to include any medium that is capable of storing or encoding a set of instruction for execution by the machine and that causes the machine to perform any one or more of the methodologies of the present invention. The term "machine-readable storage medium" shall accordingly be taken to include, but not be limited to, solid-state memories, and optical and magnetic media.

The components and other features described herein can be implemented as discrete hardware components or integrated in the functionality of hardware components such as ASICs, FPGAs, DSPs or similar devices. In addition, these components can be implemented as firmware or functional circuitry within hardware devices. Further, these components can be implemented in any combination of hardware devices and software components.

Some portions of the detailed descriptions are presented in terms of algorithms and symbolic representations of operations on data bits within a computer memory. These algorithmic descriptions and representations are the means used by those skilled in the data processing arts to most effectively convey the substance of their work to others skilled in the art. An algorithm is here, and generally, conceived to be a self-consistent sequence of steps leading to a desired result. The steps are those requiring physical manipulations of physical quantities. Usually, though not necessarily, these quantities take the form of electrical or magnetic signals capable of being stored, transferred, combined, compared, and otherwise manipulated. It has proven convenient at times, principally for reasons of common usage, to refer to these signals as bits, values, elements, symbols, characters, terms, numbers, or the like.

It should be borne in mind, however, that all of these and similar terms are to be associated with the appropriate physical quantities and are merely convenient labels applied to these quantities. Unless specifically stated otherwise, as apparent from the above discussion, it is appreciated that throughout the description, discussions utilizing terms such as "enabling", "transmitting", "requesting", "identifying", "querying", "retrieving", "forwarding", "determining", "passing", "processing", "disabling", or the like, refer to the action and processes of a computer system, or similar electronic computing device, that manipulates and transforms data represented as physical (electronic) quantities within the computer system's registers and memories into other data similarly represented as physical quantities within the computer system memories or registers or other such information storage, transmission or display devices.

Embodiments of the present invention also relate to an apparatus for performing the operations herein. This apparatus may be specially constructed for the required purposes or it may comprise a general purpose computer selectively activated or reconfigured by a computer program stored in the computer. Such a computer program may be stored in a computer readable storage medium, such as, but not limited to, any type of disk including floppy disks, optical disks, CD-ROMs and magnetic-optical disks, read-only memories (ROMs), random access memories (RAMs), EPROMs, EEPROMs, magnetic or optical cards, flash memory devices including universal serial bus (USB) storage devices (e.g., USB key devices) or any type of media suitable for storing electronic instructions, each of which may be coupled to a computer system bus.

The algorithms and displays presented herein are not inherently related to any particular computer or other apparatus. Various general purpose systems may be used with programs in accordance with the teachings herein or it may prove convenient to construct more specialized apparatus to perform the required method steps. The required structure for a variety of these systems will be apparent from the description above. In addition, the present invention is not described with reference to any particular programming language. It will be appreciated that a variety of programming languages may be used to implement the teachings of the invention as described herein.

It is to be understood that the exemplary embodiments are merely illustrative of the invention and that many variations of the above-described embodiments may be devised by one skilled in the art without departing from the scope of the invention. The scope of the disclosure should, therefore, be determined with reference to the appended claims, along with the full scope of equivalents to which such claims are entitled.

What is claimed is:

1. A method, comprising:

overlaying, by a computer processor of the mobile device, a shape graphic on a fixed area of a screen of the mobile device;

searching, by a camera of the mobile device, the fixed area for a ball with a marking authorized by the mobile device for enabling calibration and tracking;

recognizing, by the computer processor, the authorized marking on the ball;

calibrating, by the computer processor, characteristics of the ball in the overlayed shape graphic for tracking of the ball in view of the authorized marking on the ball;

tracking and recording, by the camera, data pertaining to the movement of the ball;

calculating, by the computer processor, one or more metrics relating to ball controlling abilities from the data; and

displaying, by the computer processor, the one or more metrics on the screen, wherein the one or more metrics are calculated and displayed while ball tracking pertaining to the movement of the ball is taking place;

displaying, by the processing device, a training video of a character or person executing movements of the ball on the screen of the mobile device; and

comparing, by the processing device, the movements of the ball in the training video to the movements of the ball while ball tracking is taking place.

2. The method of claim **1**, wherein the computer processor calculates the one or more metrics and displays the one or more metrics responsive to the computer processor detecting that the ball is no longer in motion or a specified time is reached.

3. The method of claim 1, wherein the marking is a logo.

4. The method of claim 1, wherein the camera is a front-facing camera of the mobile device.

5. The method of claim 1, wherein the one or more metrics are calculated and displayed in real-time.

6. The method of claim 1, wherein recognizing applies to balls with specific brands or markings.

7. The method of claim 1, wherein recognizing the marking on the ball further comprises applying feature recognition computer vision algorithms to data captured by the computer processor pertaining to the marking.

8. The method of claim 7, wherein the feature recognition computer vision algorithms comprise at least one of cross-correlation feature recognition or image matching.

9. The method of claim 1, wherein the marking is recognized based on at least one of image, text, or shape.

10. The method of claim 1, wherein calibrating further comprises recognizing one or more colors of the marking and the ball, lighting conditions, or ball pixel diameter.

11. The method of claim 1, further comprising determining, by the computer processor, ball color spectrum for color blob detection while tracking the movement of the calibrated ball.

12. The method of claim 1, wherein tracking the movement of the calibrated ball comprises employing color blob detection, shape recognition, or movement filtering.

13. The method of claim 1, further comprising displaying, by the screen, a live video feed while the computer processor is tracking the ball.

14. The method of claim 1, wherein responsive to the camera tracking position of the ball on the screen, the computer processor calculates and stores the centroid of the ball, a frame timestamp, and a ball pixel diameter in a memory.

15. The method of claim 1, further comprising estimating, by the computer processor, depth movement of the ball by examining ball pixel area in the recorded tracking data.

16. The method of claim 15, wherein estimating depth movement of the ball comprises comparing the pixel diameter of the ball to the original pixel diameter acquired during calibration.

17. The method of claim 1, further comprising, looking up, by the computer processor in a memory of the mobile device, preloaded diameter of the ball corresponding to the marking detected; and

dynamically determining physical scale for different balls with different markings.

18. The method of claim 17, converting pixel tracking to physical tracking of the ball in a three-dimensional space in view of determining physical scale.

19. The method of claim 18, further comprising,

analyzing pixel movement of the ball in three dimensions; and

estimating true physical movement in real three-dimensional space.

20. The method of claim 1, wherein the ball is a basketball and the one or more metrics comprises at least one of dribble rate, crossover-width, location consistency, maximum dribble height, dribble rate variance, dribble speed, or dribble fatigue.

21. The method of claim 1, wherein the ball is a soccer ball and the one or more metrics comprises at least one of juggle location consistency, maximum height, and number of juggles.

22. The method of claim 1, further comprising providing a training program that employs the data.

23. A mobile device, comprising:

a memory;

a computer processor, operatively coupled to the memory;

a screen, coupled to the computer processor; and

a camera, coupled to the computer processor, the camera to:

search a fixed area of the screen for a ball with a marking authorized by the mobile device for enabling calibration and tracking; and

track and record data pertaining to the movement of the ball;

the computer processor to:

overlay a shape graphic on the fixed area of the screen;

recognize the authorized marking on the ball;

calibrate characteristics of the ball in the overlayed shape graphic for tracking of the ball in view of the authorized marking on the ball;

calculate one or more metrics relating to ball controlling abilities from the data;

display the one or more metrics on the screen, wherein the one or more metrics are calculated and displayed while ball tracking pertaining to the movement of the ball is taking place;

display a training video of a character or person executing movements of the ball on the screen of the mobile device; and

compare the movements of the ball in the training video to the movements of the ball while ball tracking is taking place.

24. The mobile device claim 23, wherein the one or more metrics are calculated and displayed in real-time.

25. The mobile device of claim 23, further comprising a positioning apparatus, wherein the mobile device is configured to be placed in the positioning apparatus.

26. The mobile device of claim 25, wherein the mobile device is configured to be placed in the positioning apparatus at a high enough angle to permit video capture of the ball, the user, and a floor on which the user stands.

27. The mobile device of claim 26, wherein the angle is between sixty and ninety degrees.

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